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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Improvements in or relating to Electric Variable Frequency Oscillators.

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of Connaught House, 63 Aldwych, London, W.C.2, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

The present invention relates to adjustable frequency oscillation generator circuits which can be set to any desired frequency within a predetermined range, and to a predetermined degree of precision.

It is often required that the degree of precision shall be of the order of 0.001% or better, and that the accuracy of any frequency setting shall be higher than this. In such cases it is usually also required in the interests of convenience that any desired frequency can be set up by a dial switch arrangement (or the like), usually on a decimal or decade basis.

To meet these requirements, a number of arrangements have already been proposed in which any frequency set up is automatically standardised or controlled with reference to one (or a few) primary standard frequencies which is or are stabilised to an accuracy at least equal to that desired for any frequency setting of the generator. Such arrangements employ collections of oscillators, mixers, and frequency dividers and multipliers, and sometimes also counting chains.

The present invention is concerned with improvements to such oscillation generator circuits, and provides an electric oscillator circuit tunable over a frequency range in discrete steps including means to generate oscillations and to feed them through a pair of mixers in cascade, each mixer being followed by a respective filter and being coupled to the output of a respective local oscillator tunable to a number of discrete nominal frequencies, the filters selecting the sum frequency output of one mixer and the difference frequency output of the other mixer of the pair, means to beat together the local oscillator outputs and to compare the beat frequency with a harmonically related series of crystal controlled standard oscillations, means responsive to the frequency comparison to adjust the frequency of one local oscillator of the pair whereby the beat frequency is accurately referred to the standard oscillations, means to control the frequency of the generated oscillations with reference to one of the standard oscillations, and means to sweep the frequency of the generated oscillations operative only when the control is lost to assist in its being regained.

The invention will be described with reference to the accompanying crawings, in which :—

Fig. 1 shows a block schematic circuit diagram of an embodiment of the invention ;

Figs. 2 and 3 respectively show block schematic circuit diagrams to two elements of Fig. 1 ;

Fig. 4 shows a block schematic circuit diagram of another embodiment of the invention ; and

Fig. 5 shows details of one of the elements of Fig. 4.

No details are shown of those elements of Figs. 1 to 4 which are conventional.

In order to make the invention clear, it will be assumed that the frequency generator circuit is required to provide any output frequency F1 within the range 3 megacycles per second (Mc/s) to 6.999875 Mc/s, in steps of 125 cycles per second (c/s).

A standardised oscillation of frequency 100 kilocycles per second (Kc/s) is used to maintain the frequency corresponding to every setting of the frequency control at the indicated value by a phase-locking system which will be described later. It will be understood that the invention is not restricted to the particular frequency ranges and values which are used for illustration.

In the case of the embodiment shown in Fig. 1, the desired output frequency will be assumed to be set up by means of five dial switches, which are not illustrated, by which are arranged to set the frequencies of certain oscillators in the circuit, as will be explained later. The control by the switches may be arranged in any suitable way. In order to simplify the description of the circuit, the switches will be numbered from I to V and their functions are indicated in the following Table I:—

TABLE I.

Switch No.	No. of Positions	Frequency Range	Frequency Step
I	4	3 to 6 Mc/s	1 Mc/s
II	10	0 to 900 Kc/s	100 Kc/s
III	10	0 to 90 Kc/s	10 Kc/s
IV	10	0 to 9 Kc/s	1 Kc/s
V	8	0 to 875 c/s	125 c/s

In Fig. 1, the principal oscillator 1 provides the output oscillations of frequency F1, which can be set by means of the switches to any value within the range 3 to 6.999875 Mc/s. The oscillations are supplied to an output conductor 2 through an amplifier 3, which is preferably provided with automatic gain control, not shown. The frequency of the oscillator 1 is set to the nearest 10 Kc/s by means of switches I, II and III. No finer adjustment is necessary, since the oscillator 1 is provided with a frequency control device 4 by which the finer frequency adjustments are carried out, as will be explained later.

The frequencies produced by the circuit are accurately maintained by a standard fixed frequency oscillator 5, which supplies standard waves of a frequency 100 Kc/s which is maintained constant to a high degree of accuracy. The standard waves are supplied to a frequency generator 6 which comprises frequency multipliers and dividers arranged in conventional manner to provide five sub-standard waves of frequencies 1 Mc/s; 100, 10 and 1 Kc/s; and 125 c/s.

The oscillator 1 is connected to a mixing circuit 7 which comprises three mixing stages and includes the necessary local oscillators and filters. The local oscillations are phase-locked by means of the sub-standard waves of frequencies 1 Mc/s, and 100 and 10 Kc/s from the generator 6, so that the nominal frequencies as set by the dials are maintained accurate. The local oscillator frequencies are set by means of switches I and II in such manner that the frequency F2 at the output of the mixing circuit 7 is within the range 110.125 to 210 Kc/s.

The process of " phase-locking " which is employed in the embodiments of the invention will be explained as follows:—

The nominal frequencies provided by all the local oscillators are chosen to be integrally related to the standard frequency of 100 Kc/s, each being an integral multiple of one or other of the sub-standard frequencies. In general, therefore, the frequency of the oscillator which is controlled is an integral multiple of the sub-standard frequency used for the control. The phases of two waves can only be properly compared when they have the same frequency. However, what is required in the present case is to ensure that the frequency of one wave is an exact integral multiple of the frequency of the other, and this is carried out by a device which in effect detects changes of phase. This device is either a phase discriminator, in which case the frequencies of the two waves are made equal by a frequency change of one of them before phase comparison, or the phase detecting device is a gate which in effect detects changes in the time spacing of salient points (such as cross-overs) of the two waves.

The waves at the output of the mixer 7 are supplied to a phase discriminator 8, to which are also supplied over conductor 9 oscillations of frequency F3 from a comparison oscillator circuit 10 in the lower part of Fig. 1. This oscillator circuit is controlled by the sub-standard waves of frequencies 1 and 10 Kc/s. from the generator 6. The frequency F3 is set by the switches III, IV and V, and provides the last three stages of the setting of the output frequency F1. The actual value of F3 lies between 110.125 and 210 Kc/s.

The output of the phase discriminator 8 is connected through a low-pass filter 8A, and over conductor 11 to the frequency control device 4, and controls the frequency of the principal oscillator 1, in known manner, so that the frequency F2 is maintained equal to the frequency F3. The frequency of the oscillator 1 is thus approximately set to the nearest 10 Kc/s by the switches 1, II and III, and is then adjusted automatically to the set value to the nearest 125 c/s by the control from the phase discriminator 8, and is maintained in this adjustment.

The cut-off frequency of the filter 8A should be above 10 Kc/s so that the frequency control can act quickly enough to pick up the frequency deviations of the oscillator.

As, however, it is possible for the automatic frequency control over conductor 11 to be lost, particularly when the frequency of the oscillator 1 is being re-set by the switches, a low-frequency scanning oscillator 12 is connected to conductor 11. This oscillator has a frequency F4 which may, for example, be 10 c/s and provides a frequency-sweep of, say, 200 Kc/s for the oscillator 1. This will enable the frequency control from the phase discriminator 8 to be regained, and as soon as control is regained, the impedance presented by conductor 11 to the oscillator 12 falls to a low value due to the negative feed back of the frequency control, and the increased load on the oscillator 12 is made to stop it oscillating.

However, as soon as frequency control is lost, the oscillator 12 starts up so that frequency control is regained as described.

The frequency control device 4 may take any suitable form. It could, for example be a reactance valve or like device, or a variable capacity device, forming part of the oscillator circuit of the oscillator 1.

The comparison oscillator circuit 10 is similar to the main oscillator circuit already described. It comprises an initial oscillator 13 which is phase-locked to the sub-standard wave of frequency of 1 Kc/s and produces an output frequency F5 which has any one of the eight values 17.125 to 18.0 Kc/s in steps of 125 c/s, selectable by switch No. V.

A comparison oscillator 14 provided with a frequency control device 15 supplies the waves of frequency F3 to conductor 9, also to a three-stage mixing circuit 16 generally similar to 7, and controlled by the sub-standard waves of frequencies 1 and 10 Kc/s from the generator 6. The frequency of the oscillator 14 is set by means of the switches III, IV and V.

The frequency at the output of the mixing circuit 16 is F6 which lies within the range 17.125 to 18 Kc/s and which is set by switches III and IV.

The waves of the frequencies F5 and F6 are supplied to a phase discriminator 17 which controls the frequency control device 15 through a low pass filter 17A and over conductor 18 so that the frequency F6 is made equal to the frequency F5. The cut-off frequency of the filter 17A should exceed 100 c/s. Since, as already explained, F2 is made equal to F3, it follows that the output frequency F1 must be that corresponding to the setting of the five dial switches.

A scanning oscillator 19 similar to 12 and operating at frequency F4 is connected to conductor 18 in order to re-establish the automatic frequency control of the oscillator 14, if it should be lost.

An alarm device 20 is connected to the mixer 7 and is supplied with the standard frequency 125 c/s from the generator 6. This alarm device, which will be described in more detail below, is adapted to give notice when the frequency control of the oscillator 1 has been lost.

The switch No. 1 may be arranged to tune the oscillator 1 in 1 Mc/s steps by coil-changing, and the switches II and III in steps of 100 and 10 Kc/s by moving suitable dust cores. This oscillator does not require any high degree of precision in tuning since its frequency is automatically controlled over a range of 10 Kc/s. The switch No. III may adjust the frequency of the oscillator 14 by coil-changing, and switches IV and V by selecting capacitors. Again, high precision for the setting of the frequency of this oscillator is not necessary. However, the frequency F5 of the oscillator 13 must be accurate, and it is therefore locked to the 1 Kc/s sub-standard waves.

Fig. 2 shows the details of the mixer circuit 7 of Fig. 1, together with the alarm device 20. The mixer circuit comprises three conventional mixers 21, 22, 23 followed by respective band-pass filters 24, 25 and 26 connected in cascade. The output of the principal oscillator 1 of Fig. 1 is connected to the input of the mixer 21, and the output of the filter 26 is connected to the phase discriminator 8 of Fig. 1.

Local crystal-controlled oscillators 27, 28 and 29 are provided respectively for the mixers 21, 22 and 23. The oscillators provide output frequencies as given in Table II below :—

TABLE II.

Oscillator	Output Mc/s Frequency
27	18.1 20.1
28	21.0 22.0
29	2.31, 2.81 2.41, 2.91 2.51, 3.01 2.61, 3.11 2.71, 3.21

In each of these oscillators a separate piezo-electric crystal is provided for each frequency, the crystals being selected by the corresponding switches.

The filter 24 selects the upper sideband from the mixer 21, which has a frequency lying in the range 23.1 to 25.099875 Mc/s, while the filter 25 selects the lower sideband whose frequency lies within the range 2.1 to 3.099875 Mc/s. The two crystals of each of the oscillators 27 and 28 are selected by switch No. I in such manner that lower sideband frequency from the mixer 22 will always be in the last-mentioned range. Likewise one of the ten crystals which control the oscillator 29 is selected by switch No. II so that the lower sideband frequency F2 from the mixer 23 lies within the range 110.125 to 210.000 Kc/s.

The accuracy of the frequency-change produced by the two mixers 21 and 22 depends on the accuracy of the difference between the frequencies of the two oscillators 27 and 28. This frequency-difference F7 is accurately maintained by means of the sub-standard waves of frequencies 100 Kc/s and 1 Mc/s from the frequency generator 6 (Fig. 1). The outputs of the oscillators 27 and 28 are applied to a mixer 30 and the lower sideband is selected by a low pass filter 31. This sideband has the difference frequency F7, which can be any one of the frequencies 0.9, 1.9, 2.9 or 3.9 Mc/s, and is applied to a further mixer 32. The local heterodyne source for this mixer is a pulse generator 33 to which the 1 Mc/s sub-standard waves from the generator 6 are supplied. A spectrum of frequencies is thereby produced spaced by 1 Mc/s. The output of the mixer 31 is supplied to a tuned amplifier 34 tuned to 100 Kc/s, and this will select the lower sideband at this frequency generated from the corresponding selected oscillator frequency, and the nearest spectrum frequency.

The amplifier 34 could alternatively be a flat gain amplifier followed by a band-pass filter (not shown) designed to select the 100 Kc/s sideband.

The selected sideband at 100 Kc/s is supplied to a phase discriminator 35 together with the sub-standard wave at 100 Kc/s from the generator 6, Fig. 1. The output from the phase discriminator 35 is applied through a low-pass filter 36 to the frequency control device 37 for the oscillator 28. In this way the frequency of the oscillator 28 is controlled in such manner that the difference frequency F7 is maintained accurately at one of the four possible values.

The frequency of the oscillator 29 is maintained in like manner at the selected one of the ten frequencies given in Table II, by elements 38 to 43, which correspond respectively to elements 32 to 37. In this case no elements corresponding to 30 and 31 are required. The 100 Kc/s sub-standard wave from the generator 6 is supplied to the pulse generator 39 which produces a spectrum of waves of frequencies differing by 100 Kc/s. The amplifier 40 is tuned to 10 Kc/s or may be followed by a low-pass filter (not shown), and selects the lower sideband of this frequency from the mixer 38 generated by the selected one of the ten output frequencies of the oscillator 29 and the nearest spectrum frequency. The phase discriminator 41 is supplied with the sideband selected by the amplifier 40 and with the 10 Kc/s sub-standard wave from the generator 6, and its output controls the frequency of the oscillator 29 by means of the elements 42 and 43 as previously described.

The alarm device 20 of Fig. 1 comprises the remaining elements of Fig. 2. These elements are three similar normally shut gating circuits 44, 45 and 46 which are connected respectively to the outputs of the filter 26, the amplifier 34, and the amplifier 40. The 125 c/s substandard wave is supplied to a pulse generator 47 which generates very short pulses with a repetition frequency of 125 c/s which are applied periodically to open all the gate circuits 44, 45, 46. If the frequency control is operating correctly, the frequencies at all the points of connection of the gating circuits are exact multiples of 125 c/s, and so a constant output is obtained from each gating circuit, depending on the actual relative phases at the connecting points. If, however, the frequency control in one of the loops has failed, the relative phase will vary so that the output of the corresponding gating circuit will comprise a series of pulses whose amplitudes vary periodically from positive to negative values. The gating circuits are connected to respective bi-stable two-condition devices or multivibrators 48, 49, and 50 the outputs of which are connected in common to a counter circuit 51. If, for example, the frequency control of the oscillator 28 has failed, the gating circuit 45 will pass a train of pulses whose sign changes periodically, and these pulses are caused periodically to switch the bi-stable device 49 between its two stable conditions, thereby advancing the counter 51, which operates an alarm 52 after, say, 16 counts. The other bi-stable devices operate in a similar way.

It may be added that arrangements, not shown, may also be provided so that the scanning oscillator 12 of Fig. 1 operates the alarm 52 (or a separate one) when it is oscillating, thus indicating that frequency control of the main loop has failed.

Fig. 3 shows details of the mixing circuit 16 of Fig. 1, and also of the oscillator 13. The phase discriminator 17 of Fig. 1 is also shown in Fig. 3.

The mixing circuit 16 is very similar to that shown in Fig. 2, and comprises a cascade series of mixers and band-pass filters 53 to 58 similar to 21 to 26 of Fig. 2, but arranged for a different series of frequencies. Crystal controlled oscillators 59, 60 and 61 with a mixer 62 are arranged in the same way as elements 27 to 30 of Fig. 2 and the oscillators 60 and 61 are provided with frequency control devices 63 and 64 similar respectively to 37 and 38.

The mixer 62 is connected through a low pass filter 65 to a gating circuit 66 which carries out a similar function to the phase discriminator 35. The output from the gating circuit 66 controls the frequency control device 63 through a low pass filter 67. The 10 Kc/s substandard wave from the generator 6 (Fig. 1) is supplied to a pulse generator 68 which generates a train of short pulses with a repetition frequency of 10 Kc/s which are applied to control the gating circuit 66.

A gating circuit 69 is connected to the output of the oscillator 61 and controls the frequency control device 64 through a low pass filter 70. The 1 Kc/s substandard wave is supplied to a pulse generator 71, which produces short pulses with a repetition frequency of 1 Kc/s for controlling the gating circuit 69.

It will be seen that the frequency control arrangements are generally similar to those of Fig. 2, with the following differences: first that there are no frequency changes similar to those produced by the mixers 32 and 38 of Fig. 2, and second, that the phase discriminators 35 and 41 of Fig. 2 are replaced by gating circuits 66 and 69 in Fig. 3.

The frequencies provided by the oscillations 59, 60 and 61 are given in the following Table III and are determined by corresponding piezo-electric crystals :—

TABLE III.

Oscillator	Output Frequency
59	F9 2.00, 2.02, 2.04, 2.06, 2.08 Mc/s
60	F10 2.07, 2.08 Mc/s
61	103, 104, 105, 106, 107, 108, 109, 110, 111, 112 Kc/s

The frequencies of the oscillators 59 and 60 are selected by switch No. IV so as to produce an upper sideband frequency within the range from 2.190,125 to 2.210,000 Mc/s selected by the filter 54, and a lower sideband frequency within the range from 120.125 to 130.00 Kc/s selected by the filter 56. The frequency of the oscillator 61 is selected by the switch No. V so as to produce a lower sideband frequency F6 within the range from 17.125 to 18.000 Kc/s selected by the filter 58.

In this case the frequency of the wave selected by the filter 56 will be F3 + (F9 — F10), where F9 and F10 are the frequencies of the oscillators 59 and 60. It will be seen that, having regard to the frequencies F9 and F10 as given in Table III (F9 — F10) will have any one of ten values +10, 0, —10, —20, ... —80 Kc/s. The filter 65 selects from the mixer 62 the lower sideband of frequency F8 which is equal to the positive difference between F9 and F10, and so will have any one of the nine values 0, 10, 20 ... 80 Kc/s. The cut-off frequency of the low pass filter 65 should accordingly be slightly above 80 Kc/s.

So long as the frequency F8 is zero or an exact multiple of 10 Kc/s, and that the wave is appropriately phased with respect and to the 10 Kc/s substandard wave, the output from the gating circuit 66 will be substantially zero. However, any slight change in frequency of the oscillator 60 will cause a phase shift so that an output will be obtained from the gating circuit which corrects the change by means of the frequency control device 63. The gating circuit 69 operates in like manner to correct the frequency of the oscillator 61. Gating circuits are used in Fig. 3 instead of phase discriminators because the two applied frequencies are generally not equal, but one is always a multiple of the other.

The oscillator 13 of Fig. 1 comprises the remaining elements of Fig. 3. It includes a crystal-controlled oscillator 72 which provides by means of separate crystals any one of 8 frequencies equally spaced by 1 Kc/s from 137 to 144 Kc/s. One of these frequencies is selected by switch No. V and the corresponding wave is passed through a frequency divider 73, which divides by 8, to the phase discriminator 17. The frequency applied to the phase discriminator is accordingly F5, which is one of the 8 frequencies 17.125 to 18.000 Kc/s. As already mentioned, F6 is automatically maintained equal to F5.

The frequency of the oscillator 72 is controlled in the same way as that of the oscillator 61 by means of a gating circuit 74, a low pass filter 75 and a frequency control device 76, the output of the pulse generator 71 being used to control the gating circuit 74.

Fig. 4 shows an alternative form of a frequency generator circuit providing the same range of frequencies as that of Fig. 1. In this case the final output frequency is built up in successive mixer stages by an addition process. All the oscillators concerned are phase-locked to the substandard waves and there are no main frequency control loops such as are produced by the condutors 11 and 18 in Fig. 1. The phase locking arrangements are similar to those in Fig. 2 and 3 except that the frequencies employed are different, and so these arrangements will not be again described in detail.

The circuit of Fig. 4 comprises a series of four mixers 77 to 80 connected in a cascade series with corresponding output bandpass filters 81 to 84. The waves at the output of the filter 84 have a frequency F1 adjustable by means of five dial switches as indicated in Table I to any frequency in the range 3 to 6.999875 Mc/s in steps of 125 c/s. The waves are delivered through an amplifier 85 to an output conductor 86. The amplifier 85 is provided with an automatic gain control device 87 on conventional lines. The A.G.C. voltage which indicates the output level is supplied to a conductor 88 for a reason which will be explained later.

Five local oscillators 89 to 93 are connected to the mixers 77 to 80, as indicated. These oscillators provide certain frequencies determined by piezo electric crystals selectable by the switches. The oscillator 89 is connected to the mixer 77 through a frequency divider 94 which divides by 8. The oscillators 92 and 93 connected to the mixers 79 and 80 are also connected to a mixer 95 and to a phase-locking loop similar to that associated with the elements 27, 28 and 30 of Fig. 2. A phase locking loop similar to that associated with the oscillator 29 in Fig. 2 is connected to the oscillator 91 of Fig. 4. The phase locking loops associated with the oscillators 89 and 90 are similar to that associated with the oscillator 91 except that the phase discriminator 96 is replaced by gating circuits 97 and 98.

Table IV below gives the frequencies supplied by the five oscillators, and the switches by which they are controlled :—

TABLE IV.

Osc.	Frequency			Switch No.	Frequency From 94 : Kc/s	
89	352	356	Kc/s	V	44.000	44.500
	353	357			44.125	44.625
	354	358			44.250	44.750
	355	359			44.375	44.875
90	351	356	Kc/s	IV		
	352	357				
	353	358				
	354	359				
	355	360				
91	3.555	3.605	Mc/s	III		
	3.565	3.615				
	3.575	3.625				
	3.585	3.635				
	3.595	3.645				
92	35.05	35.55	Mc/s	III		
	35.15	35.65				
	35.25	35.75				
	35.35	35.85				
	35.45	35.95				
93	33	35	Mc/s	I		
	34	36				

The frequency ranges at the outputs of the bandpass filters 81 to 84 are given in Table V.

TABLE V.

Filter	Frequency Range	
81	395.000 to	404.875 Kc/s
82	3.950,000 to	4.049,875 Mc/s
83	39.000,000 to	39.999,875 Mc/s
84	3.000,000 to	6.999,875 Mc/s

The phase-locking loops are controlled by the standard oscillator 5 as in Fig. 1, and a frequency generator 99, similar to 6, except that the sub-standard frequencies which it produces are 1, 5, 20, 50, 200 and 350 Kc/s. It will be seen that the mixers 100 and 101 in the control loops of the oscillators 89 and 90 are supplied with the 350 Kc/s substandard wave while the corresponding gating circuits 97 and 98 are supplied with the 1 Kc/s substandard wave.

The phase-locking loop of the oscillator 91 is controlled by the 5 Kc/s substandard wave supplied to the phase discriminator 96, and by a frequency spectrum derived from a pulse generator 102 supplied with the 20 Kc/s substandard wave. Finally, the phase-locking loop of the oscillators 92 and 93 is controlled by the 50 Kc/s substandard wave supplied to the phase discriminator 103, and a frequency spectrum derived from a pulse generator 104 supplied with the 200 Kc/s substandard wave.

It may be pointed out that although the frequencies at the output of the oscillator 92 differ in steps of 100 Kc/s, each of them has been chosen to be a multiple of 50 Kc/s (see Table IV), thus each one of them will differ by 50 Kc/s from the nearest one of the 200 Kc/s spectrum frequencies from the pulse generator 104, thereby producing a difference frequency of 50 Kc/s for comparison with the 50 Kc/s substandard wave in the phase discriminator 103. Spectrum frequencies differing by 100 Kc/s could have been used, but this would involve higher orders of multiplication to produce the spectrum frequencies, and a lower and less convenient difference frequency would have to be chosen.

A low-frequency scanning oscillator 105 is provided, as in Fig. 1, for regaining frequency control if it should be lost in any of the four phase-locking loops. The oscillator 105 is connected through a transformer coupling device 106 and over four separate conductors to points in the phase-locking loops at the inputs of the frequency control devices, as indicated. Details of the coupling device 106 are shown in Fig. 5. In this figure, the four frequency control devices F.C., and the corresponding low pass filters LPF of Fig. 4 are shown, and also the oscillator 105. The device 106 comprises four similar transformers 107 to 110, the primary windings of which are connected in series to the output of the oscillator 105. The secondary winding of each transformer is connected between ground and the conductor connecting the corresponding low-pass filter LPF and frequency control device F.C. as shown. Normally, when all the control loops are operating, the negative feedback effectively present in each loop makes the impedance connected to the secondary winding of each transformer have a low value so that the total load impedance connected to the oscillator 105 is too small to permit it to oscillate. However if the control is lost in any of the four loops, that loop will present a high impedance, so increasing the load impedance connected to the oscillator so that it can start up, and causes the control to be regained. The oscillator 105 may be arranged to operate an alarm device 111 when it is oscillating; for example, by rectifying the oscillations and applying the rectified current to an alarm relay (not shown). Under ordinary conditions control will usually be regained very quickly, so that the alarm will only be operated momentarily. But if some fault prevents the control from being regained at all, a permanent alarm will be given.

The conductor 88 is also connected to the oscillator 105 so that, if as a result of a fault, no output is produced on the conductor 86, the A.G.C. voltage supplied over conductor 88 causes the oscillator 105 to start, thereby operating the alarm.

If desired, arrangements (not shown) operated by the oscillator 105 may be provided to disconnect the output conductor 86 (or otherwise to prevent any output) if frequency control in any of the locking loops should be permanently lost due to some fault.

It will be understood that other choices of frequencies could be made in the embodiments of the invention which has been described. The choices are governed by considerations well understood by those skilled in the art. For example, the frequency of the sideband selected from the mixer 21 (Fig. 2) has been chosen to avoid the third harmonic of the frequency of the oscillator 1 in order to simplify the filtering. Again, the frequencies of the oscillator 29 are chosen to differ from the frequencies of the nearest harmonics of 100 Kc/s by 10 Kc/s, so that the frequencies of the two waves applied to the phase discriminator 41 can be made equal.

In Fig. 3, a relatively high frequency has been chosen for the sideband selected from the mixer 53 in order that conveniently available crystals can be used in the oscillators 59 and 60. Likewise, the divider 73 is introduced in order to avoid the use of large crystals in the oscillator 72. The use of this divider also avoids the production of spurious signals with a frequency of 125 c/s.

In the embodiments which have been described to illustrate the invention, the smallest frequency step is 125 c/s. However, it is obvious that by very small modifications (such as using dividers for 73 and 94 (Figs. 3 and 4) which divide by 10 instead of by 8) the smallest step could be 100 c/s, so that switch V would have 10 positions instead of 8.

It is also evident that both embodiments could be provided with additional stages arranged on the same principles as those illustrated, so that the smallest frequency step is reduced in the ratio 10, or 100, for example.

It will be understood that amplifiers which have not been shown may be included at any points in the circuits of Figs. 1 to 4, as may be necessary.

While no details have been given of any of the elements of the circuits, they can be made up in any desired way. However, it may be mentioned that transistors can be used for all the active devices necessary in the circuits.

WHAT WE CLAIM IS:—

1. Electric oscillator circuit tunable over a frequency range in discrete steps including means to generate oscillations and to feed them through a pair of mixers in cascade, each mixer being followed by a respective filter and being coupled to the output of a respective local oscillator tunable to a number of discrete nominal frequencies, the filters selecting the sum frequency output of one mixer and the difference frequency output of the other mixer of the pair, means to beat together the local oscillator outputs and to compare the beat frequency with a harmonically related series of crystal controlled standard oscillations, means responsive to the frequency comparison to adjust the frequency of one local oscillator of the pair whereby the beat frequency is accurately referred to the standard oscillations, means to control the frequency of the generated oscillations with reference to one of the standard oscillations, and means to sweep the frequency of the generated oscillations operative only when the control is lost to assist in its being regained.

2. Circuit as claimed in Claim 1, wherein the sweep means includes a scanning oscillator coupled to a control loop in the phase locking arrangement, which control loop presents an impedance to the scanning oscillator too low for it to oscillate except when phase locking control is lost.

3. Circuit as claimed in Claim 1 or 2, including an alarm operative when phase control is lost.

4. Circuit according to Claim 1, 2 or 3, wherein the standard oscillations are waves being harmonics and sub-harmonics of the output of a crystal-controlled oscillator, including means to apply two of the waves to control the phase locking arrangement, and the means to generate oscillations, include a plurality of separate local oscillators.

5. A generator circuit according to Claim 4, in which the phase-locking arrangement comprises a control loop including means controlled by one of said two waves for changing the frequency of one of said oscillators to a value nominally equal to the frequency of the other of said two waves, a phase discriminator to which the said other wave and the wave from the oscillator after frequency change are applied, and a frequency control device connected to the oscillator and controlled by the phase discriminator in such manner as to correct any change in frequency of the oscillator tending to produce a change in the phase difference between the two waves applied to the phase discriminator.

6. A generator according to any one previous claim in which the phase-locking arrangement comprises a control loop including a gating circuit to which are applied a train of gating pulses derived from the standard wave, and having a repetition frequency equal to an integral submultiple of the standard frequency, means for applying the waves from the oscillator to the gating circuit, and a frequency control device connected to the oscillator and controlled by the output from the gating circuit in such manner as to maintain the frequency of the oscillator equal to an integral multiple of the said repetition frequency.

7. A generator circuit according to Claim 5 or 6 comprising alarm means connected to the control loop adapted to give notice of a failure of the phase-locking arrangement to maintain the frequency of the waves generated by the oscillator equal to the said value.

8. A generator circuit according to Claim 4 comprising a series of mixers connected in cascade, each mixer being provided with a corresponding local oscillator, the first mixer being provided in addition with an input-oscillator the arrangement being such that the frequency of the oscillations at the output of the last mixer in the series is formed by a combination in the mixers of the frequencies of all the said oscillators, in which each oscillator provides a limited number of frequencies differing by equal frequency steps, the frequency step being different for each oscillator.

9. An electric oscillation generator circuit according to Claim 1 including means for adjusting the output frequency of the generated oscillations to any one of a plurality of discrete values lying within a first predetermined frequency range, comprising a principal oscillator arranged to generate the said oscillations, the said principal oscillator having means for adjusting the frequency approximately to one of the said discrete values, a comparison oscillator circuit arranged to generate comparison oscillations having a frequency capable of being accurately adjusted to any one of a number of discrete frequencies lying within a second predetermined frequency range which is below, and narrower than, the first predetermined frequency range, means including one or more mixers with local oscillators for deriving from the principal oscillator derived oscillations having a frequency which is

nominally equal to a selected one of the last-mentioned discrete frequencies, means for applying the derived oscillations and the comparison oscillations to a phase discriminator, and a frequency control device connected to the principal oscillator and adapted to be controlled over a first control conductor by the output from the phase discriminator in such manner as to adjust the frequency of the principal oscillator until the two waves applied to the phase discriminator are in the same phase, and to maintain the adjustment, and further comprising a source of a standard wave having a standard frequency, and a first phase locking arrangement associated with at least one of the local oscillators and controlled by the standard wave, the phase-locking arrangement being adapted to maintain the frequency of the waves generated by the said local oscillator constant and equal to a value which is an integral multiple of an integral submultiple of the standard frequency.

10. A generator circuit according to Claim 9 further comprising alarm means controlled by the said first phase-locking arrangement, and adapted to give an alarm if the said first phase-locking arrangement should fail to maintain control of the frequency of the waves generated by the local oscillator.

11. A generator circuit according to Claim 9, in which the comparison oscillator circuit comprises an initial oscillator adjustable to produce a second comparison wave whose frequency is capable of being accurately adjusted to one of a number of discrete frequencies each of which is an integral multiple of a submultiple of the standard frequency, and lies within a third predetermined frequency range which is below, and narrower than, the second predetermined frequency range, a comparison oscillator arranged to generate the said comparison oscillations and having means for approximately adjusting the frequency of the comparison oscillations, means including one or more further mixers with further local oscillators for deriving from the comparison oscillator derived comparison oscillations having a frequency nominally equal to a selected one of the last-mentioned discrete frequencies, a second frequency control device connected to the comparison oscillator, means for applying the waves from the initial oscillator and from the comparison oscillator to a second phase discriminator connected over a second control conductor to the second frequency control device and arranged to adjust the frequency of the comparison oscillator in such manner that the two waves applied to the second phase discriminator are brought into, and maintained in, the same phase, and a further phase-locking arrangement associated with at least one of the further local oscillators, the said further phase-locking arrangement being adapted to maintain the frequency of the waves generated by the last-mentioned oscillator constant and equal to a value which is an integral multiple of a submultiple of the standard frequency.

12. A generator circuit according to Claim 11 in which means is provided for deriving from the standard wave a plurality of substandard waves of different substandard frequencies, each substandard frequency being an integral multiple or submultiple of the standard frequency, and in which the first phase-locking arrangement comprises a first control loop including means controlled by one of the substandard waves for changing the frequency of the local oscillator concerned to a frequency equal to another of the substandard frequencies, a third phase discriminator to which the substandard wave having the last-mentioned substandard frequency, and the wave from the local oscillator after frequency change are applied, and a third frequency control device connected to the local oscillator, and controlled by the said third phase discriminator in such manner as to correct any change in frequency of the local oscillator tending to produce a change in the phase discriminator.

13. A generator circuit according to Claim 12 in which the second phase-locking arrangement comprises a second control loop including a gating circuit to which are applied a train of gating pulses derived from the standard wave and having a repetition frequency equal to a submultiple of the standard frequency, means for applying the waves from the local oscillator concerned to the gating circuit, and a fourth frequency control device connected to the said local oscillator and controlled by the output from the gating circuit in such manner as to maintain the frequency of the local oscillator equal to an integral multiple of the said repetition frequency.

14. A generator circuit according to one of Claims 11, 12 or 13 comprising two low-frequency scanning oscillators respectively connected to the first and second control conductors and adapted to vary the frequency of the principal oscillator and of the comparison oscillator over a range sufficient to enable the phase discriminators to regain control of the frequencies of the corresponding oscillators should such control have been lost.

15. An electrical oscillation generator circuit substantially as described, and as illustrated in Figs. 1 to 3, or in Figs. 4 and 5, of the accompanying drawings.

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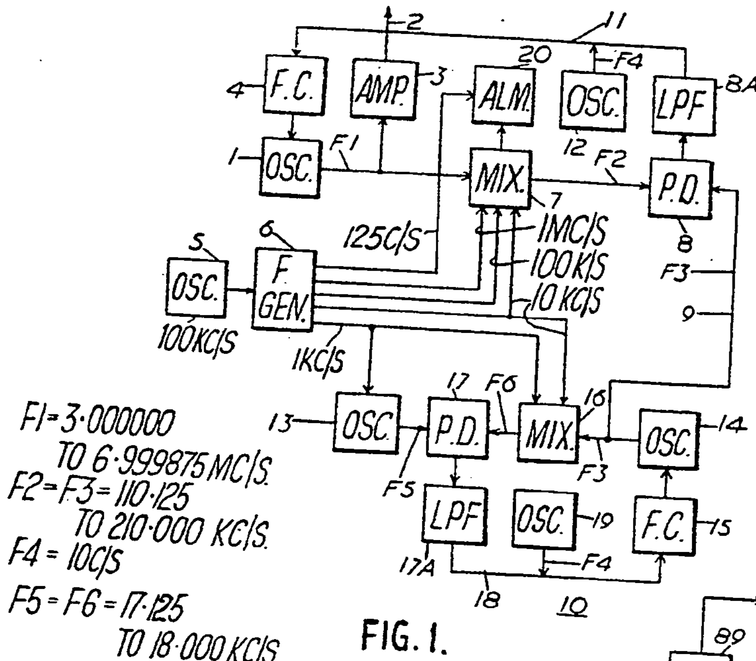
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F4 = 10C/S
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FIG. 1.

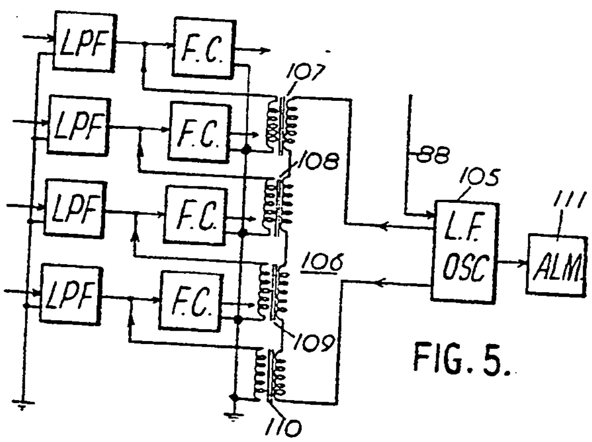
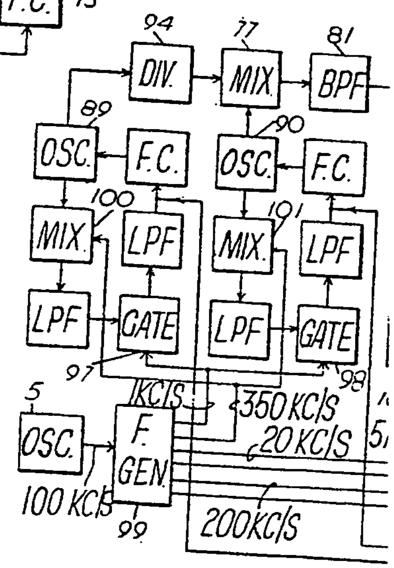


FIG. 5.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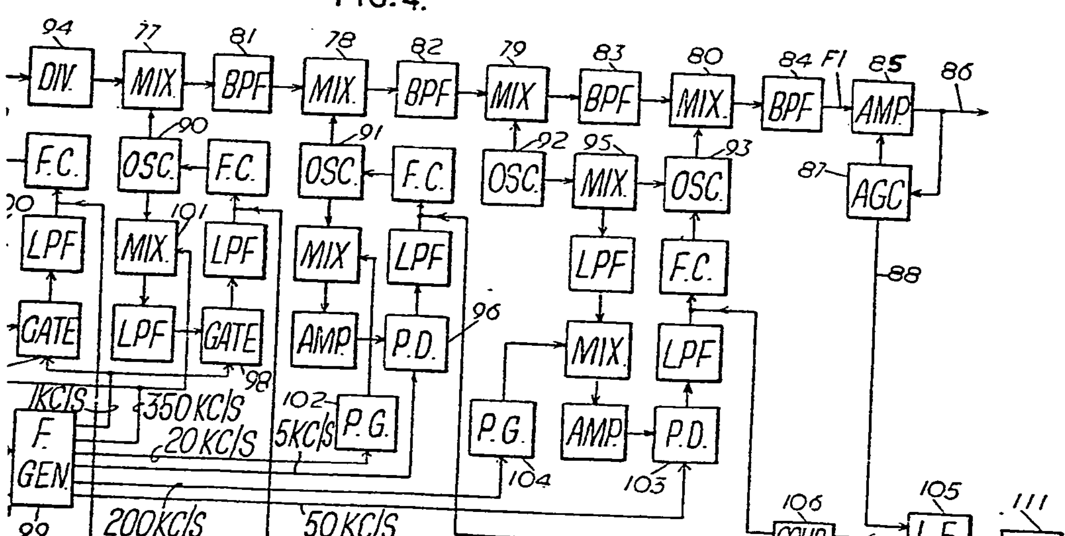
Sheet 1

FIG. 4.



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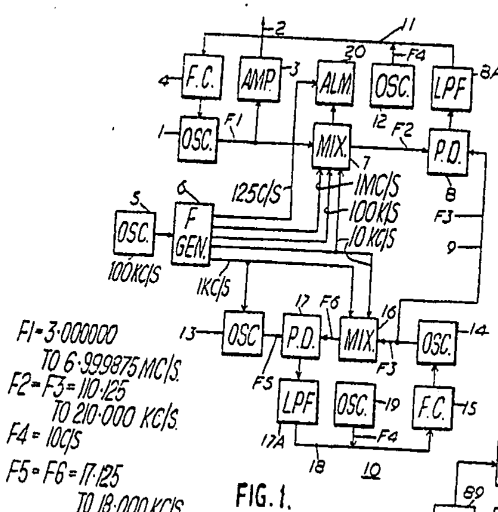
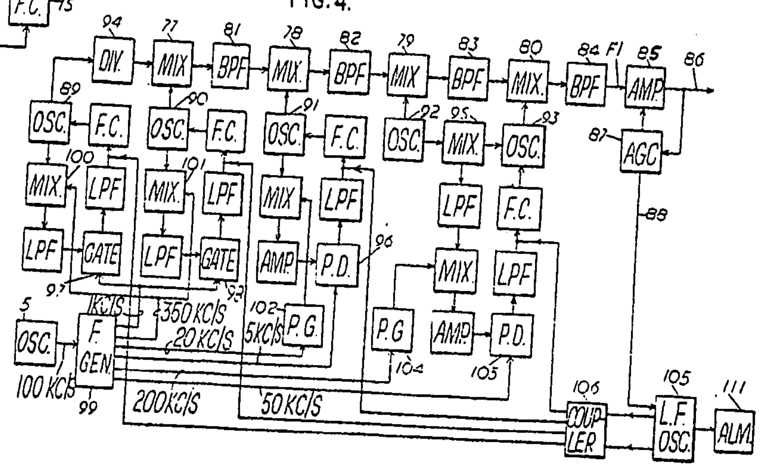


FIG. 1.



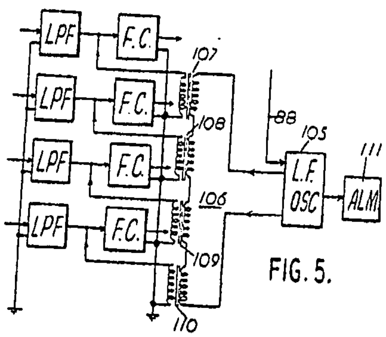


FIG. 5.

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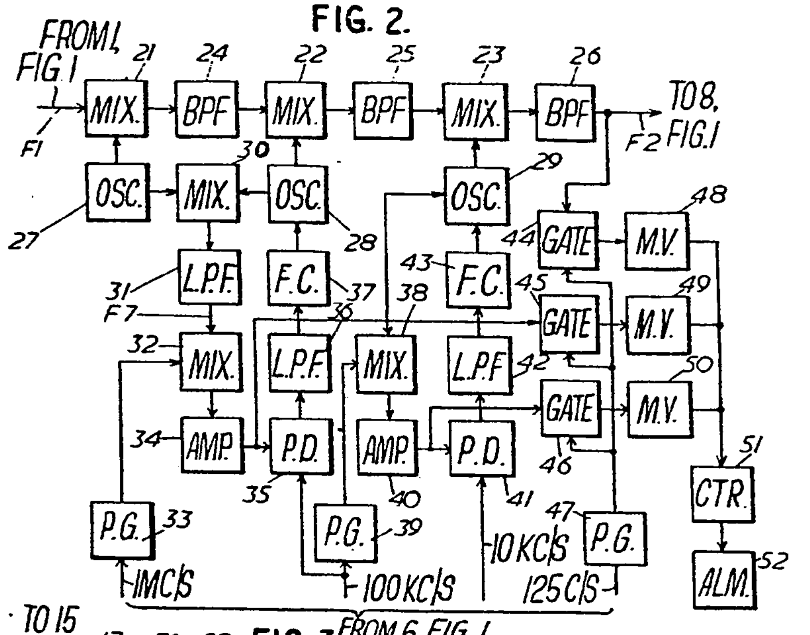
Sheet 2

FIG. 2.



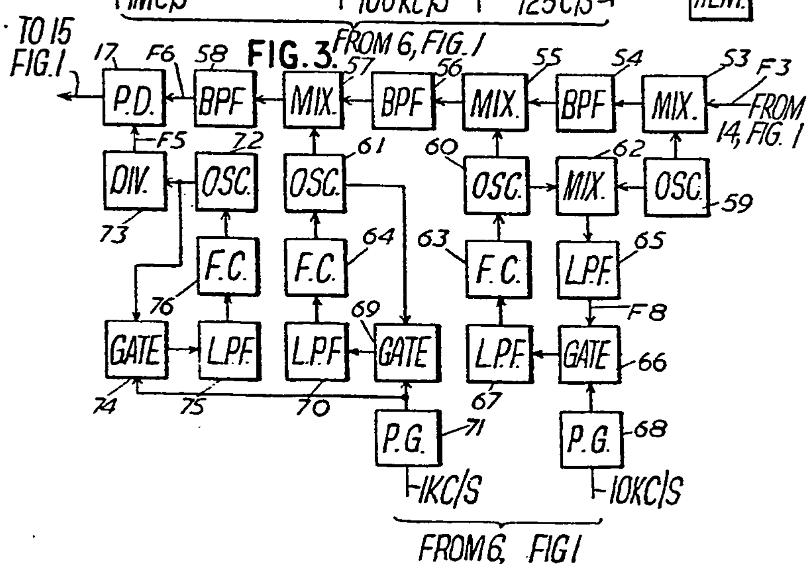


FIG. 3.